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Maximum Utility for Limited Vaccine Stocks -

A case study using agent-based modelling

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Background

- Inspired by events of September 11, 2001 and the anthrax attacks soon thereafter
- Initial work led to invitation to Project Albert Emergency Working Group on Terrorism in Maui, Hawaii, January 2002
- While initial study focused on terrorism attack, the methodology and results are equally valid for treatable transmittable epidemics such as meningococcal meningitis or measles
- In fact, results are generally applicable to any system in which something (be it disease or information) is transmitted

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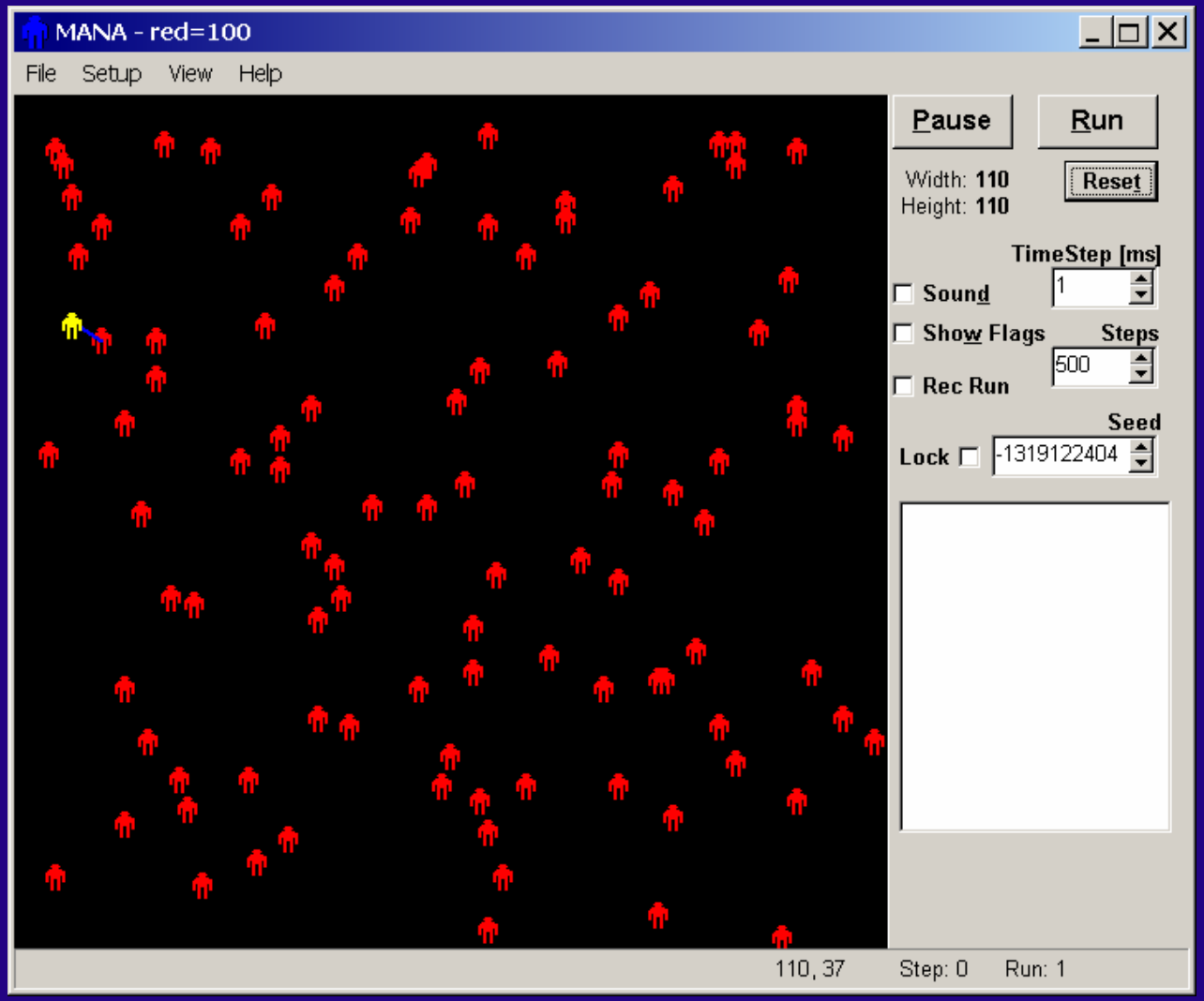
SIR Model in MANA



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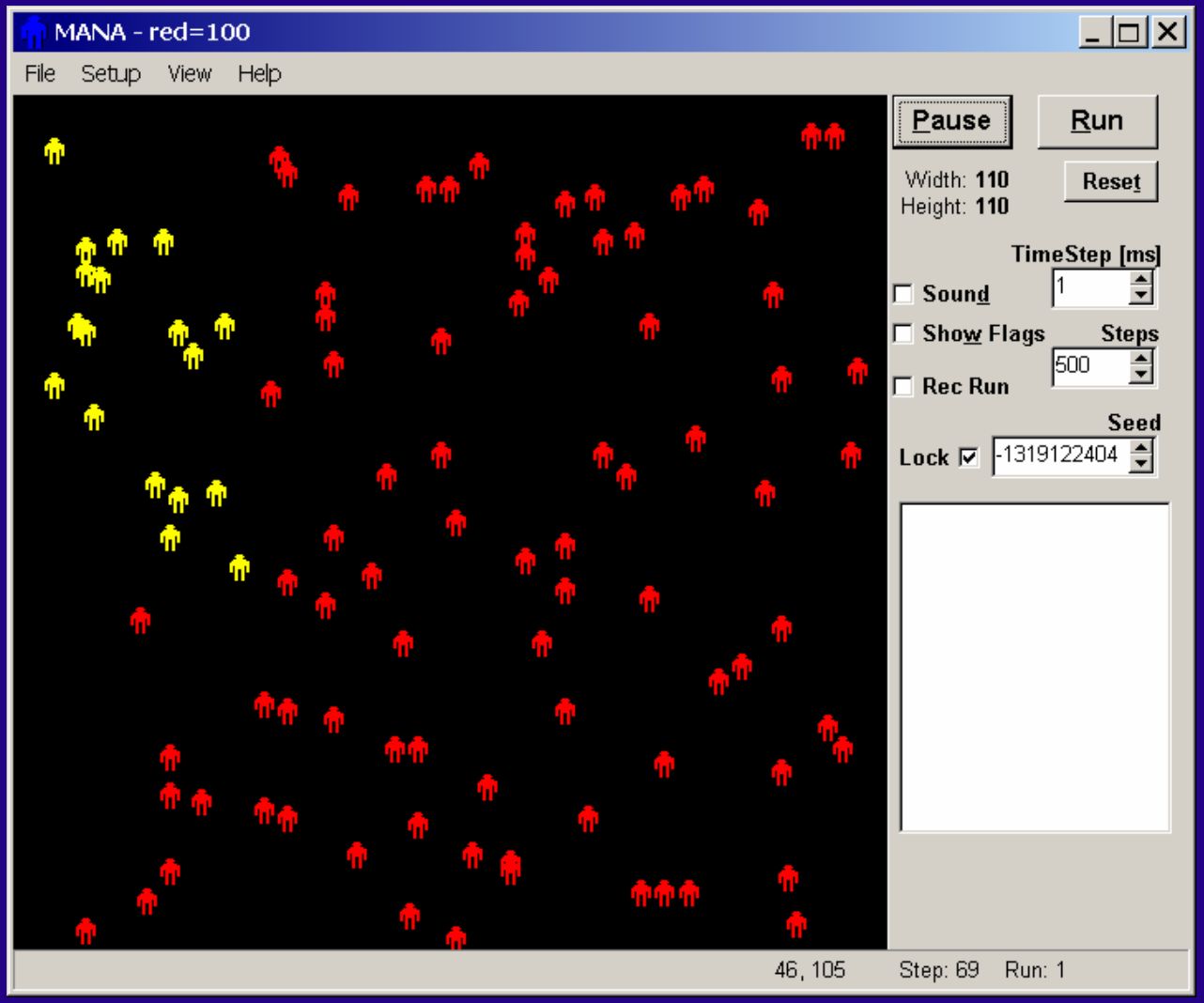

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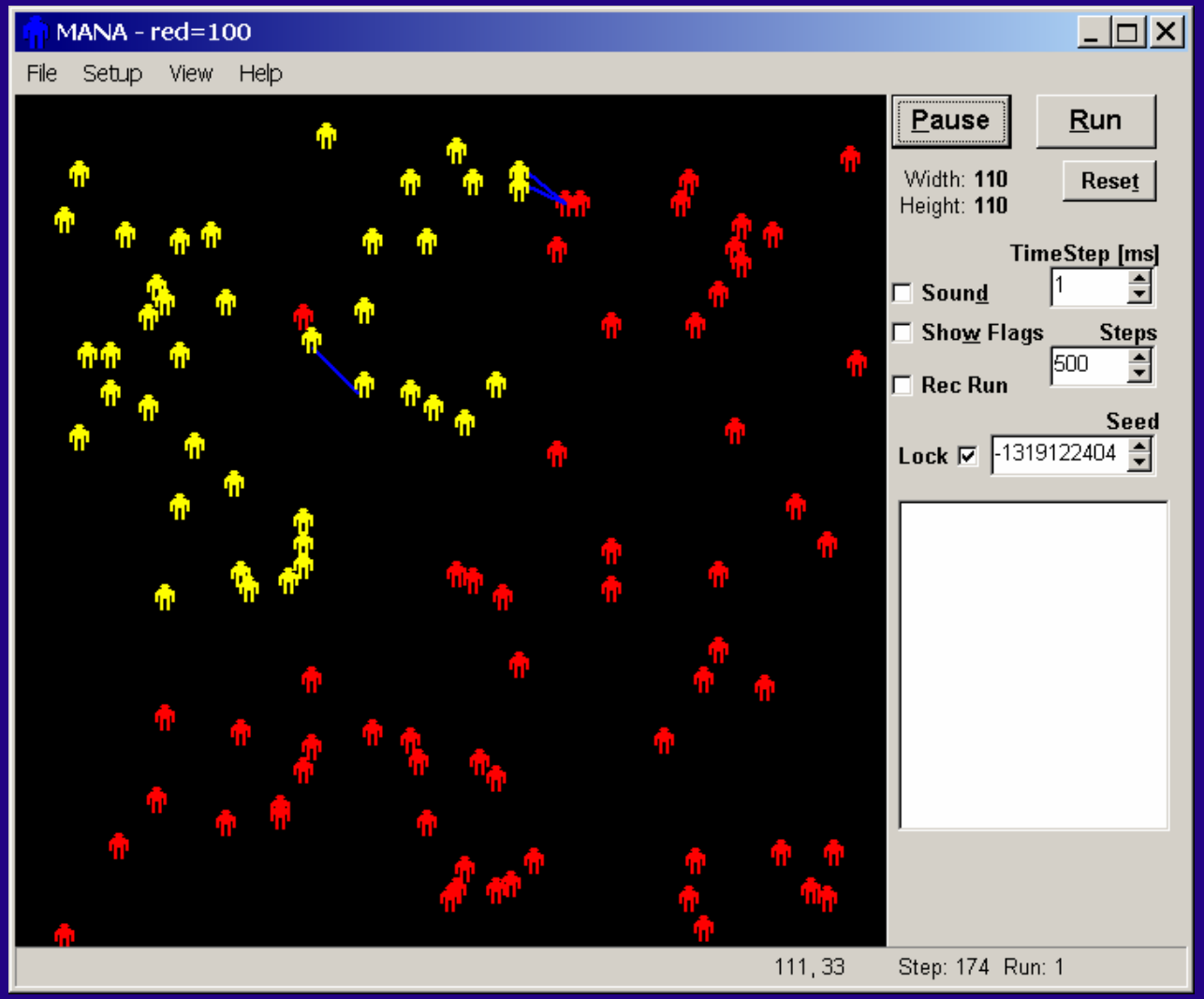

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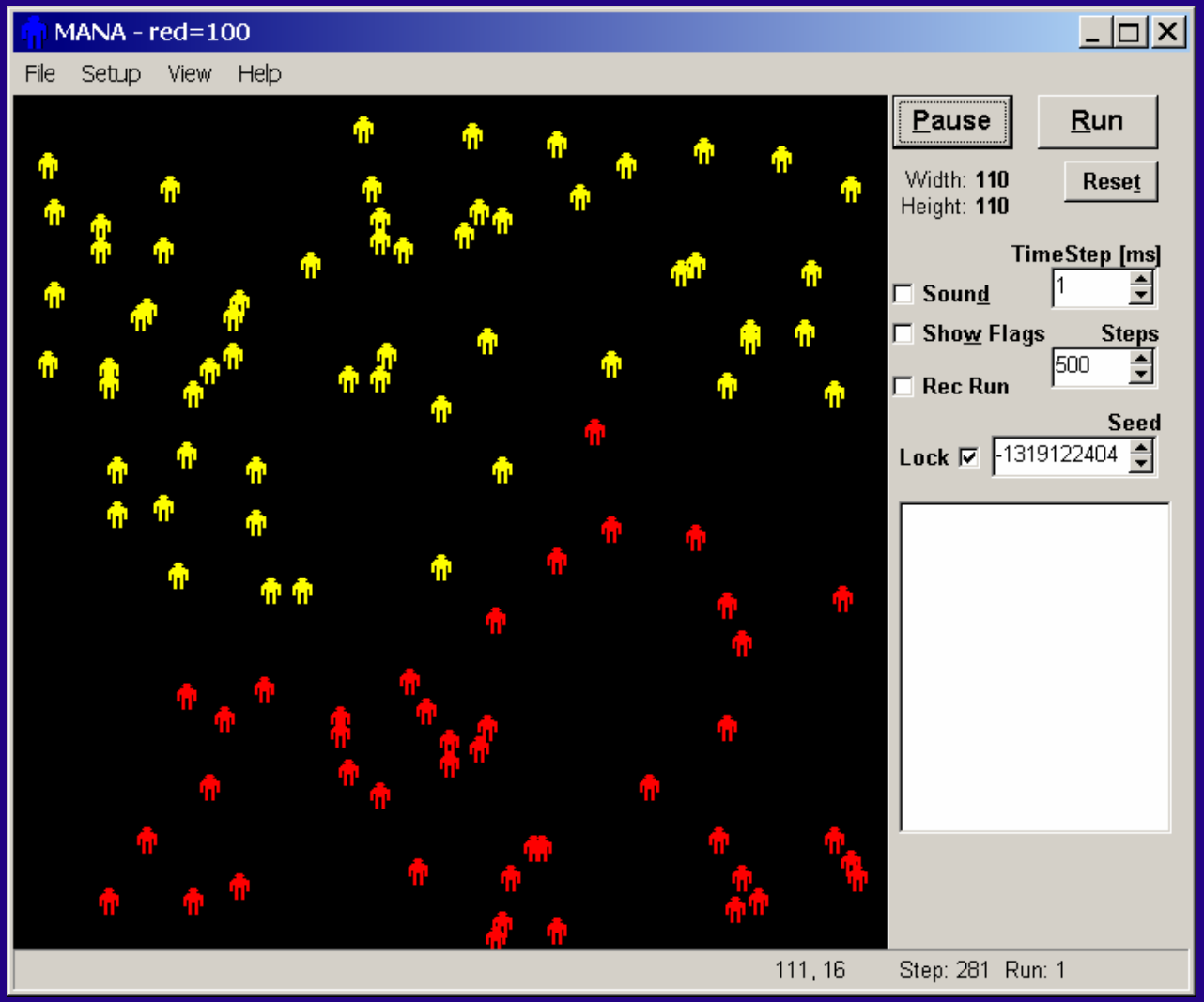


Inoculation

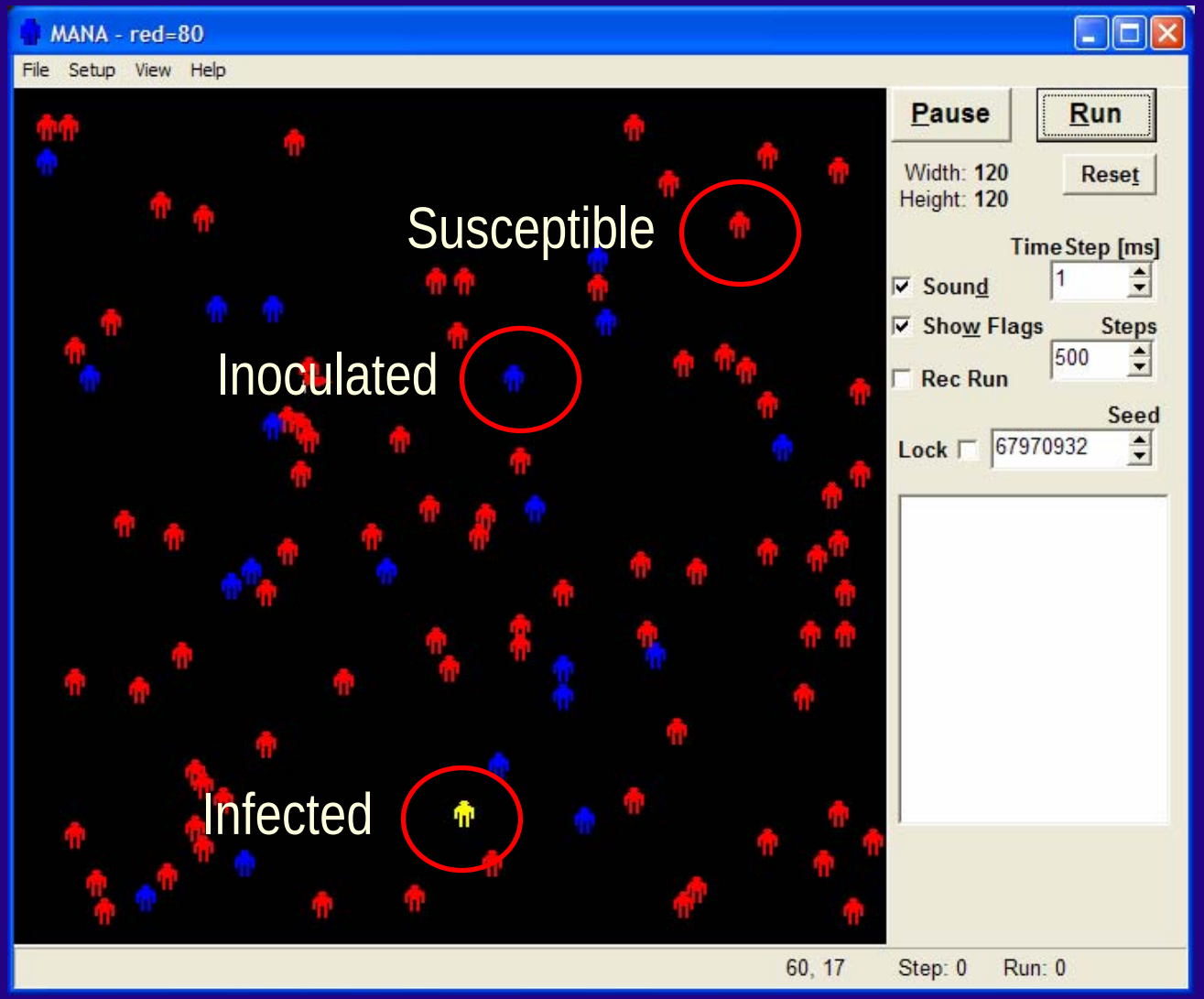
- At the time of the anthrax scare post 9/11 it was made clear that there was not enough vaccine to inoculate the entire population
- The question we examined is:

"Given a limited supply of vaccine for a communicable disease, and sufficient time to effectively vaccinate, is there an optimal strategy to vaccinate a number of independent communities?"

The Method

- The only factors varied were the proportion of inoculateds in the community and the contact number
- In MANA terms, agents were inoculated by turning them neutral, keeping the total number constant
- Susceptibles + Recovered + Infected + Inoculated = 100
- Contact Number was varied by decreasing the size of the play box
- All other factors were constant

Inoculation in MANA



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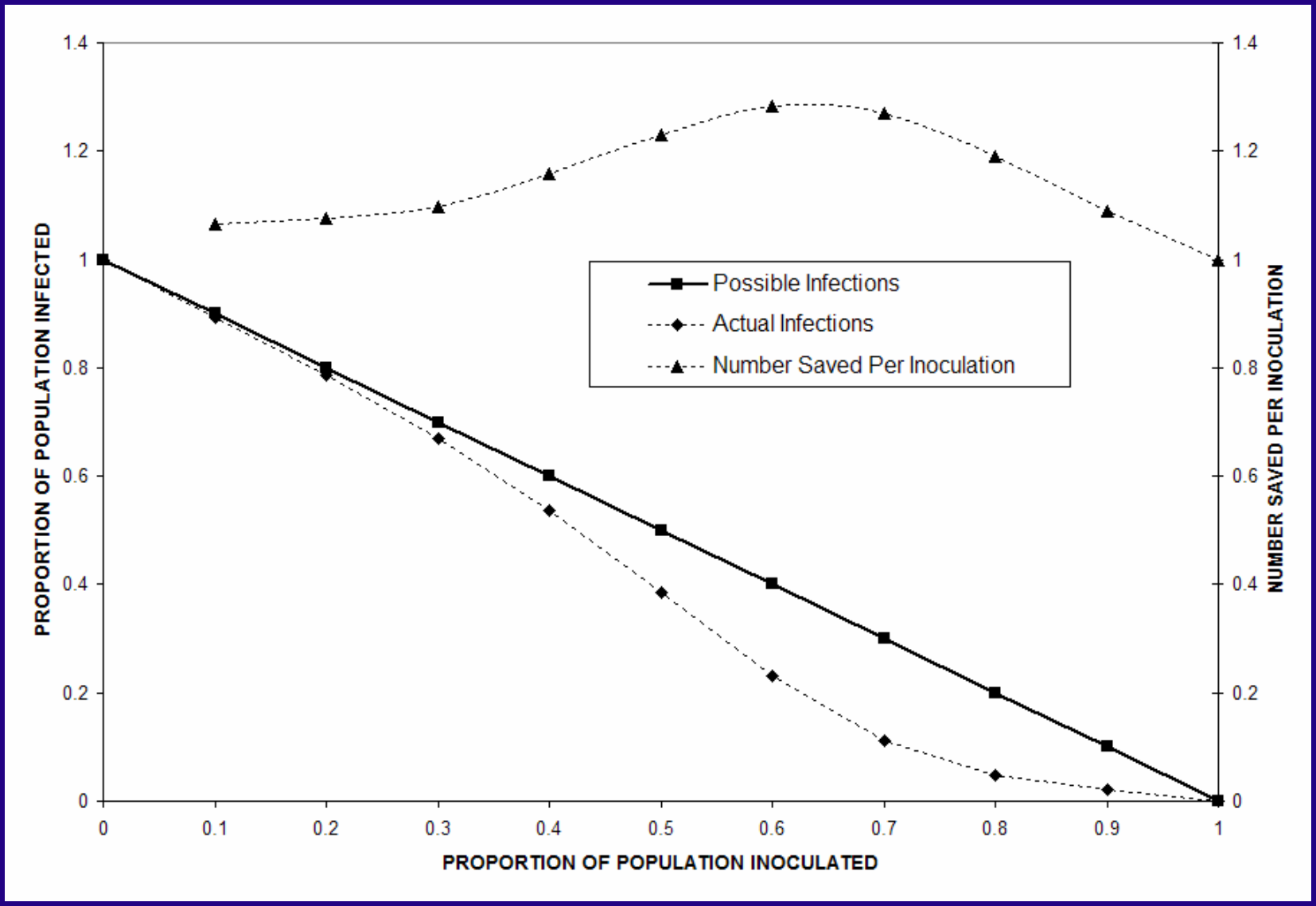
Number Saved per Inoculation



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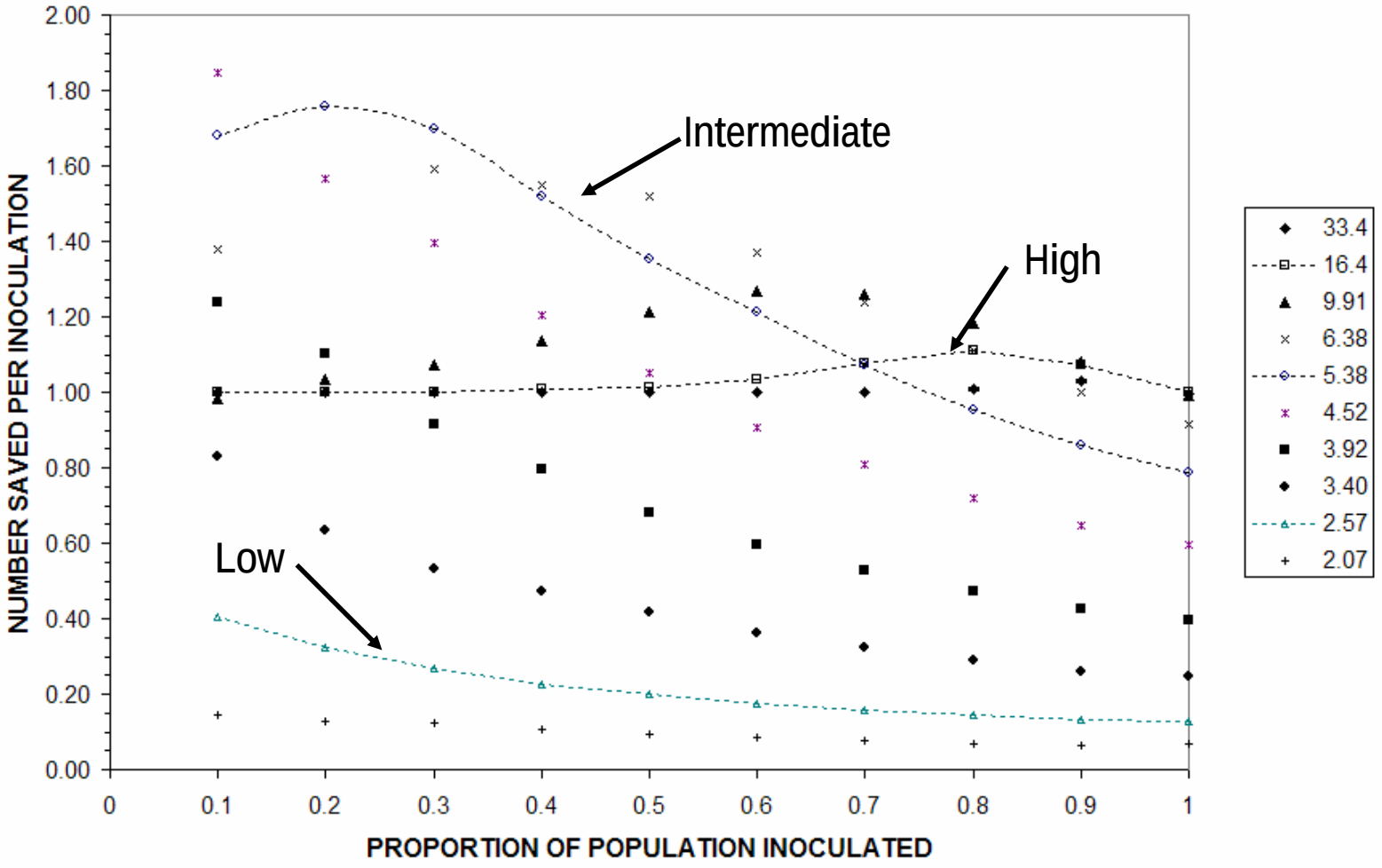
Maximum Utility from Limited Vaccinations



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Low Contact Number

- Number Saved per Inoculation (NPSI) is much less than 1
- Greatest NSPI occurs at low levels of inoculation
- With a number of communities at risk and limited inoculant the best strategy is to inoculate a small percentage from each community

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High Contact Number

- Number Saved per Inoculation (NPSI) is slightly greater than 1
- Greatest NSPI occurs at high but not maximum levels of inoculation
- Inoculating everybody cannot achieve an NSPI greater than 1
- With a number of communities at risk and limited inoculations the best strategy is to inoculate a large percentage from one community before moving on to the next

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Intermediate Contact Number

- Number Saved per Inoculation (NPSI) can be significantly greater than 1
- Greatest NSPI occurs at intermediate levels of inoculation, which varies significantly with contact number
- Added level of “Risk”
  - Flat Distribution of Infections
  - “Over-Vaccinating” significantly reduces the NSPI

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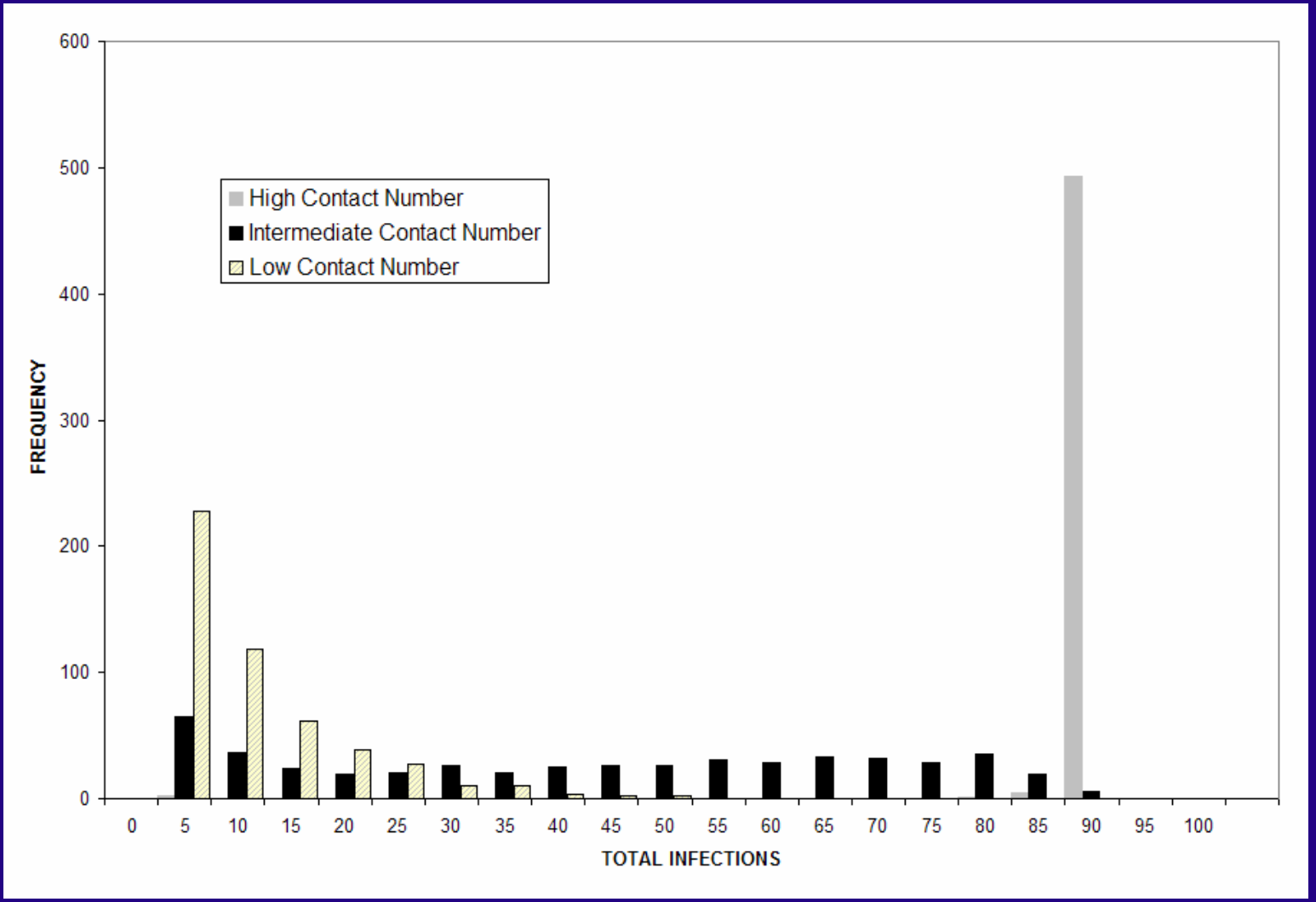
Distribution of Infections



The Modified SIR Model

- The standard epidemiological equations can be modified to include inoculation

$$\frac{ds(t)}{dt} = -bi(t)s(t)$$

$$\frac{di(t)}{dt} = bi(t)s(t) - ki(t)$$

$$\frac{dr(t)}{dt} = ki(t)$$

$$\frac{dv(t)}{dt} = 0$$

$$s + i + r + v = 0$$

- Where *b* is the individual contact number and *k* is the fraction each day that recover

The SIR Model

- Used data from the 1968-69 Hong Kong Flu Epidemic in New York City
- Population 7,900,000
- 1/3 of infected persons recover each day, as flu last for 3 days
- Vary Contact Number
- Critical Contact number when $b=k=1/3$

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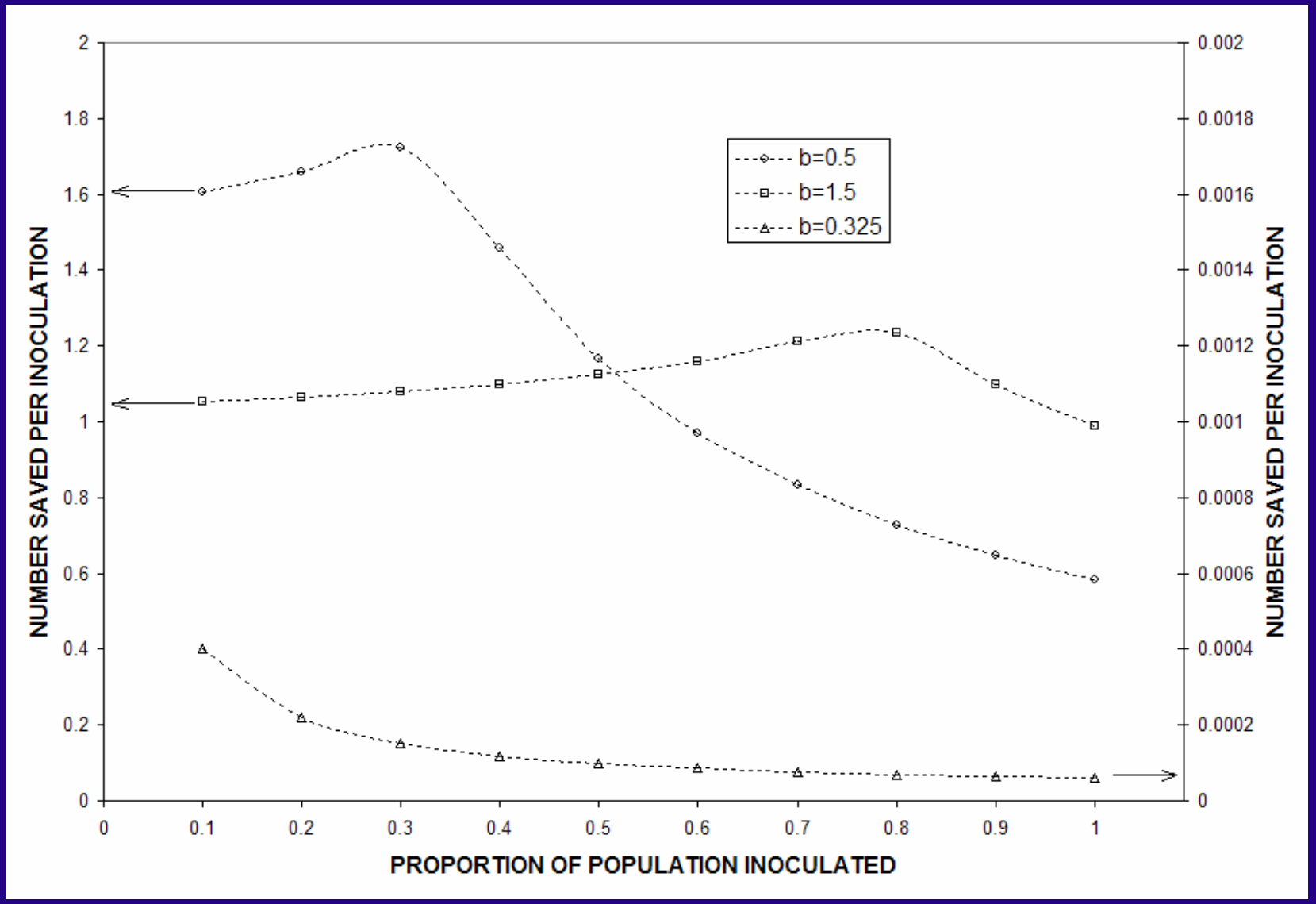
Modified SIR Model



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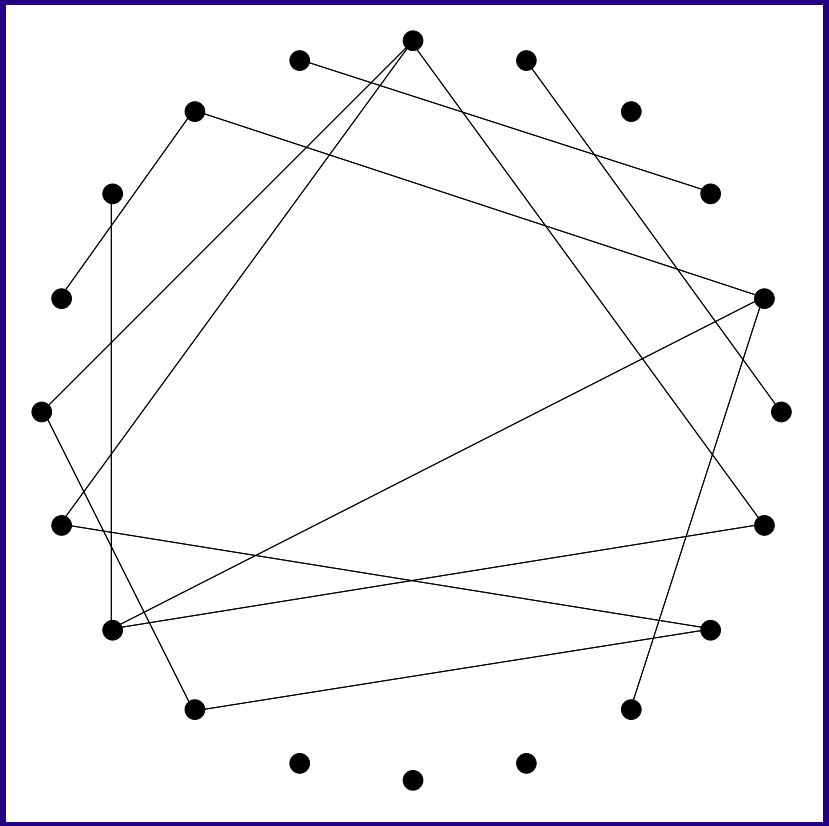
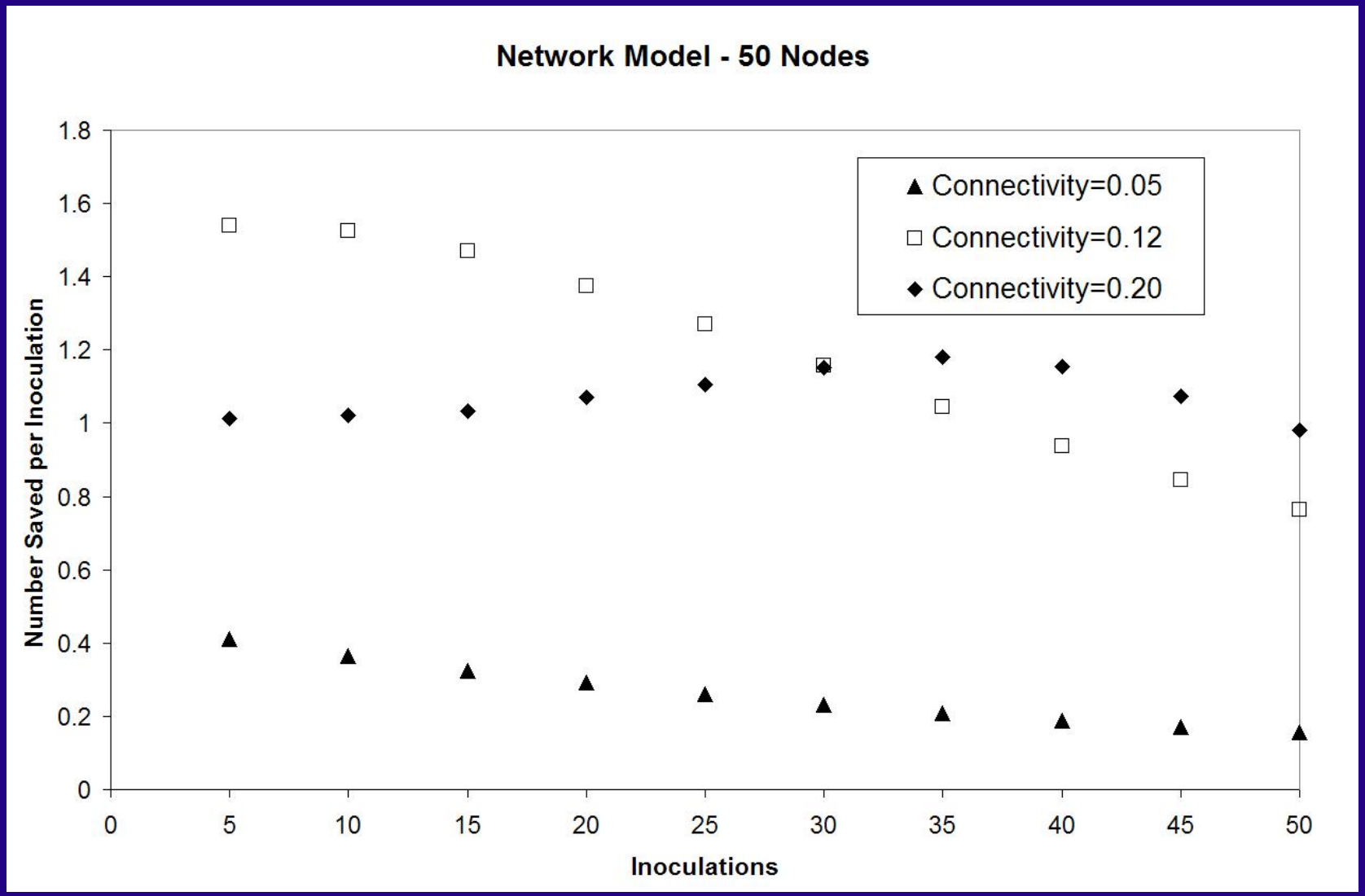
Network Model

- Random Network
- Connections represent Contacts
- Assume disease is transmitted by contact with a 100% efficiency
- Nodes removed at random
- Examine the effect on average cluster size
- This technique allows ~ 20,000 – 50,000 clusters to be examined



Network Model



Conclusions

- Demonstrates that “combat models” can be employed to examine significant non-military or non-combat related questions
- Gives insight into how best to distribute limited vaccines to prevent epidemics
- Trends confirmed by three independent methods
- Model can easily be extended to cover many network-based questions where something is transmitted from one entity to another

QUESTIONS?